O‘ZBEKISTON RESPUBLIKASI
OLIY TA’LIM, FAN VA INNOVATSIYALAR VAZIRLIGI

QARSHI DAVLAT TEXNIKA UNIVERSITETI

MEXANIKADA FAN TA’LIM VA ISHLAB CHIQARISH INTEGRATSIYASI: MUAMMOLAR, YECHIMLAR VA ISTIQBOLLAR

XALQARO ILMIY-TEXNIK ANJUMAN MATERIALLARI

ИНТЕГРАЦИЯ НАУКИ, ОБРАЗОВАНИЯ И ПРОИЗВОДСТВА В МЕХАНИКЕ: ПРОБЛЕМЫ, РЕШЕНИЯ И ПЕРСПЕКТИВЫ

МАТЕРИАЛЫ МЕЖДУНАРОДНОЙ НАУЧНО-ТЕХНИЧЕСКОЙ КОНФЕРЕНЦИИ

INTEGRATION OF SCIENCE, EDUCATION AND PRODUCTION IN MECHANICS: PROBLEMS, SOLUTIONS AND PROSPECTS

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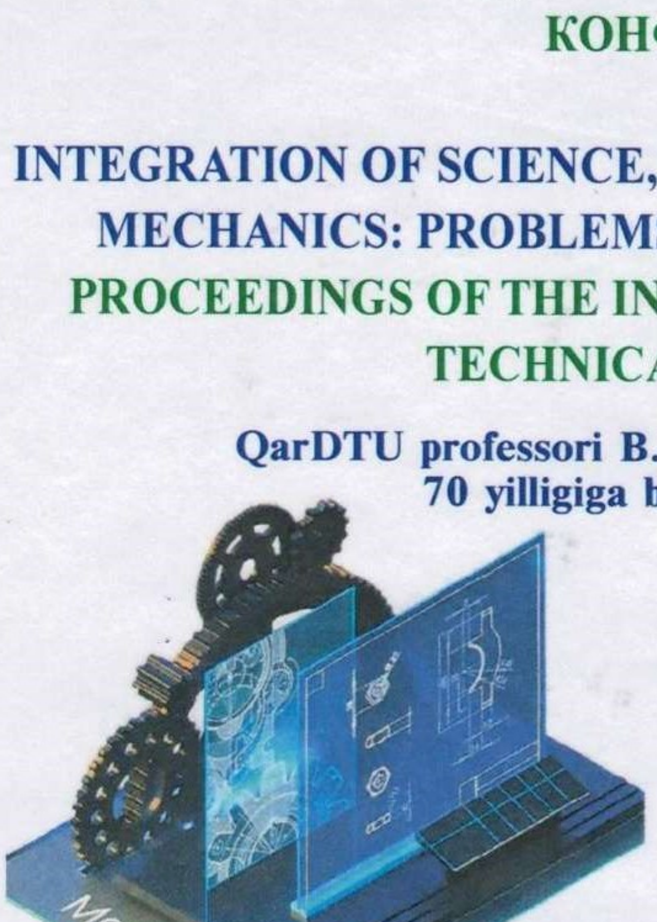

1-3 MAY
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May 1-3, 2025, Karshi

Qarshi - 2025

“Mexanikada fan, ta’lim va ishlab chiqarish integratsiyasi: muammolar, yechimlar va istiqbollar” mavzusidagi Respublika ilmiy-texnik anjuman materiallar to‘plami - Qarshi “Intellekt” nashriyoti, 2025-yil.

To‘plamda O‘zbekiston Respublikasi Oliy ta’lim, fan va innovatsiyalar vazirligining 2024 yil 27 dekabrdagi 490-sonli buyrug‘iga asosan Qarshi davlat texnika universiteti “Umumtexnik fanlar” kafedrasida 2025 yilning 1-3 may kunlari “Mexanikada fan, ta’lim va ishlab chiqarish integratsiyasi: muammolar, yechimlar va istiqbollar” mavzusidagi o‘tkazilgan Xalqaro ilmiy-texnik anjuman ishtirokchilarining ilmiy maqolalari chop etilgan.

Anjumanning asosiy yo‘nalishlari – Qattiq jismlar mexanikasi va mexanika fanining rivojlanishidagi dolzarb muammolar; ishlab chiqarish bilan mexanika fanining integratsiyasi va uning yechimlari; hozirgi zamon texnologiyalarida nanomateriallarni olish va ishlatilish istiqbollari; zamonaviy mexanikaning dolzarb muammolari, yechimlari va uni o‘qitishda innovatsion yondashuv kabi muammolarga bag‘ishlangan ilmiy maqola va tezislar jamlangan.

Mazkur to‘plam shu soha mutaxassislari, doktorantlar, magistrantlar, talabalar hamda mexanika faniga qiziquvchilar uchun mo‘ljallangan.

To‘plamdan o‘rin olgan maqolalardagi ilmiy dalillarning haqqoniyligi hamda mazmuni uchun mualliflar mas’uldirlar.

Mazkur to’plam Qarshi davlat texnika universiteti Kengashining 2025-yil 17-aprel №1-sonli qarori bilan nashrga tavsiya etildi.

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JUSTIFICATION OF THE GEOMETRICAL PARAMETERS OF THE SPHERICAL DISK AND THE INSTALLATION ANGLE

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Abstract. To make a stale seedbed or prepare a seedbed for drilling you need to ensure that the machine you are using follows the contours of the field. If not you will have areas in the field that are under or over cultivated or consolidated and this will effect the crop growth and yield at harvest. The end result is that the discs pull themselves into the ground more which assists penetration meaning more soil is inverted and residue incorporated.

Keywords: disc, soil, cultivated, horizontal, radius, determined

The disc is highly versatile, it can be used for shallow weed chits after harvest directly after the combine as well as the incorporation of stubble and other crop residues to a depth of up to in minimal tillage cultivations. It is also a superb tool for working ploughed land prior to drilling and with around tonne per metre you have an efficient consolidating press for primary and secondary cultivations. To make a stale seedbed or prepare a seedbed for drilling you need to ensure that the machine you are using follows the contours of the field. If not you will have areas in the field that are under or over cultivated or consolidated and this will effect the crop growth and yield at harvest. The end result is that the discs pull themselves into the ground more which assists penetration meaning more soil is inverted and residue incorporated. All this happens automatically and hydraulically as the depth of the discs is being altered by the operator from the tractor cab.

The main design parameters of spherical disks, which determine their impact on the soil at a particular installation relative to the line of movement of the implement, are the diameter D of the disk and the radius of curvature R (Figure 1), and

$$D=2R\cdot sin\varphi, \quad (1)$$

where φ – half angle at the apex of the sector.

The main geometric characteristics of a disk of given dimensions, determining its performance at a depth of a, when installed at an angle α (α – angle of attack, i.e. the angle between the plane of rotation of the disk and the direction of movement of the gun) to the line *m-m* of the working movement (Figure 2), are the occipital angle ε and the angle of inclination ω of the generatrix of the sharpening cone to the plane of the cutting edge. For any section of the disk by a horizontal plane, we have characteristics of a spherical disk.

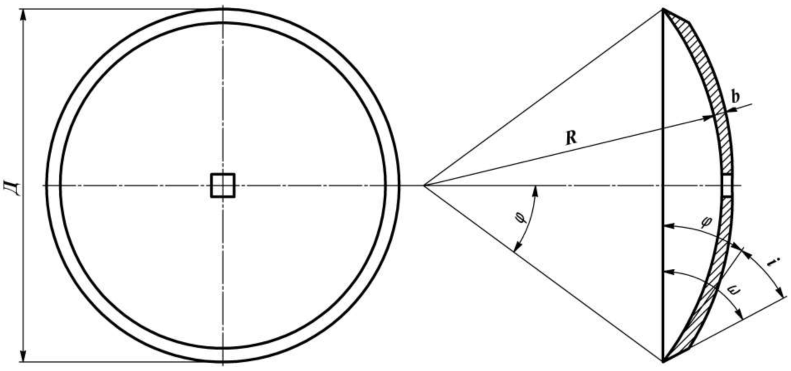


Figure 1 - Spherical disk

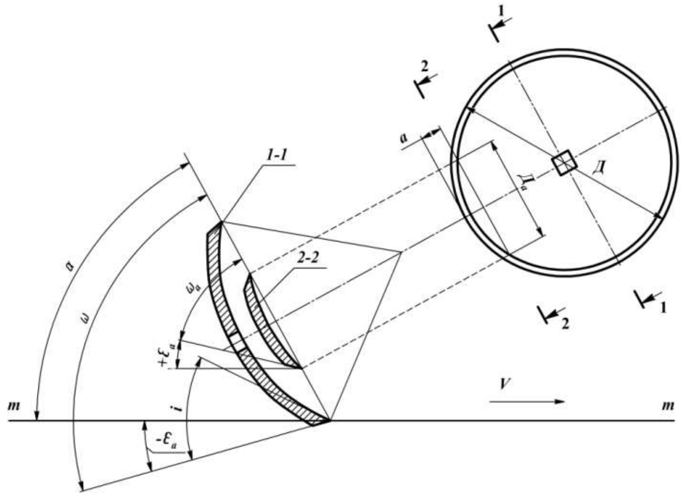


Figure 2 - Scheme for determining geometric

$$\alpha = \omega_a \pm \varepsilon_a = \omega \pm \varepsilon = const \quad (2)$$

Wher ε_a – occipital angle; ω_a – angle of inclination of the sharpening cone generatrix to the plane of the cutting edge .

The chord Da (Figure 2) of the disk immersion to a depth a is determined by the expression

$$D_a = 2\sqrt{a(D - a)} \quad (3)$$

The distance between adjacent discs of the cultivator is determined by the formula

$$b = 2\sqrt{c(D - c)} \cdot tg\alpha, \quad (4)$$

where c – height of furrow bottom ridges.

The traction resistance of a single spherical disk can be determined by the approximate formula

$$\boldsymbol{R}_x = \frac{\boldsymbol{k} \cdot D^2}{6} \sin\alpha \left(\arccos \frac{D - 2a}{D} \right)^3, \quad (5)$$

where $\boldsymbol{k}$ – soil resistivity coefficient, $\boldsymbol{k}$ =4…8 Н/см^2.

Determine the value of the occipital angle εa for a cultivator disk with a diameter D=450 мм, radius of the sphere R=450 мм, radius of the sphere a=0,12 м, angle of attack α=35° and the sharpening angle i=15°.

From the calculation schemes (Figures 1 and 2) it follows that $\varepsilon_a = \alpha - \omega_a$. (6)

It is known [6] that $$tg\omega_a = \frac{D_a}{D} \cdot tg\omega, \qquad (7)$$

That's why $$tg\omega_a = \frac{2\sqrt{a(D-a)}}{D} \cdot tg\omega \qquad (8)$$

From Figure 1 it follows that $$\omega = \varphi + i \qquad (9)$$

where i – sharpening angle.

The numerical value of the angle φ is determined by expression (9)

$$\varphi = \arcsin\frac{D}{2R} \qquad (10)$$

Solving (7), (9) and (5) together, we obtain

$$\omega_a = arctg\left\{\frac{2\sqrt{a(D-a)}}{D} \cdot tg\left(\arcsin\frac{D}{2R} + i\right)\right\} \qquad (11)$$

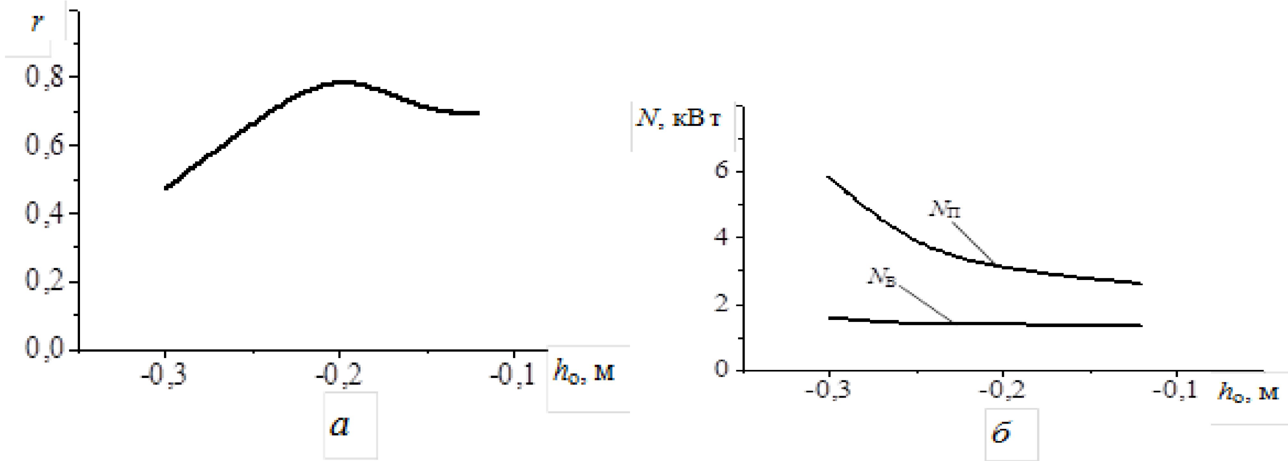


Figure 3 – Effect of the vertical position of the moldboard ho on the quality (a) and energy (b) indicators of soil cultivation: NП – power expended on the forward movement of the plow; NB – power expended on the rotation of the plow disk.

The main parameters that set the position of the moldboard in the form of a section of the plane are the transverse αo and longitudinal βo angles of the plane installation and the position ho of the point B of the joint of the moldboard and the spherical disk. To study the influence of these parameters on the efficiency of soil cultivation, three series of computer experiments were conducted based on the developed mathematical model..

The vertical position of the blade ho was changed from –0.20 to –0.10 m with a step of 0.05 m (Figure 3). On the graph of the dependence of the formation turnover coefficient on the dump installation height r(ho), a clearly defined maximum is observed at a ho value close to –0.18 m. If the moldboard is positioned too high, the layer cut by the disk, rising along the disk, is torn off from it before reaching the moldboard, therefore, at high ho, the turnover of the layer is low. If the position is too low, the blade "presses" the forming layer, does not allow it to rise along the disk, therefore the turnover of the layer r at low ho also falls. With a decrease in ho, the power of the forward movement increases sharply. This is due to the fact that the power begins to be spent on "pressing" the layer and on pulling the blade through the soil. As a result of the latter effect, the furrow profile is deformed (Figure 4, top).

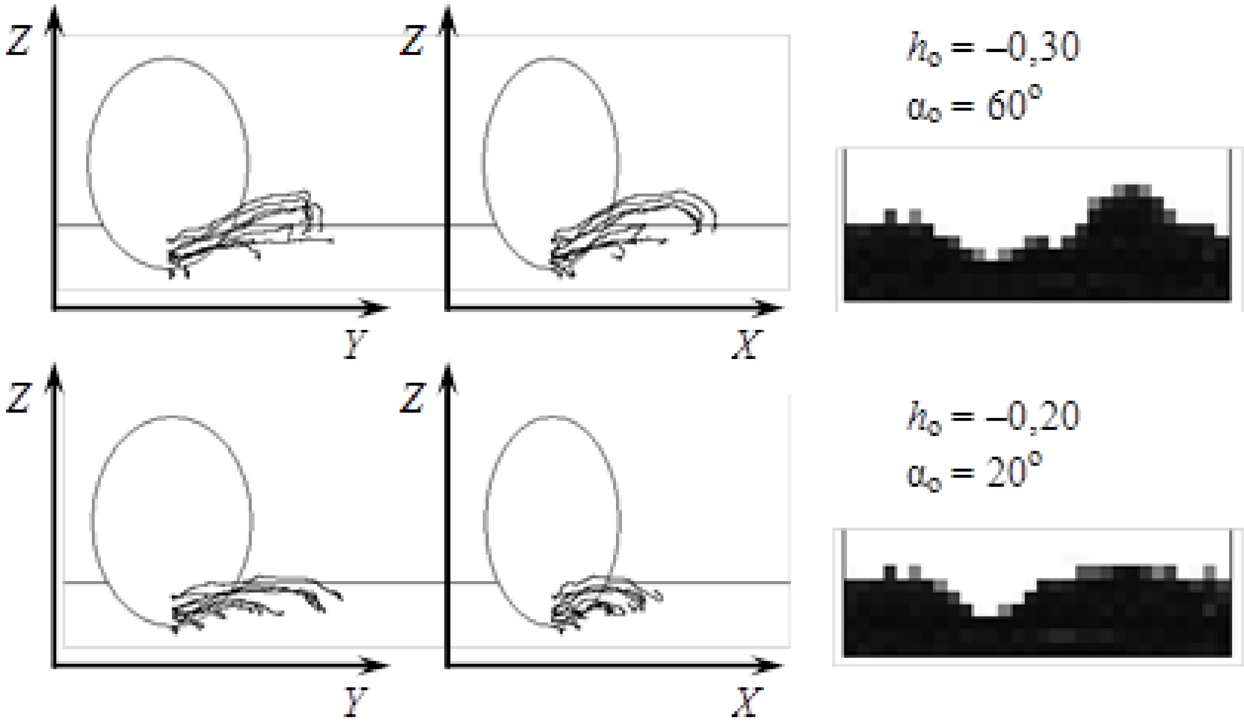
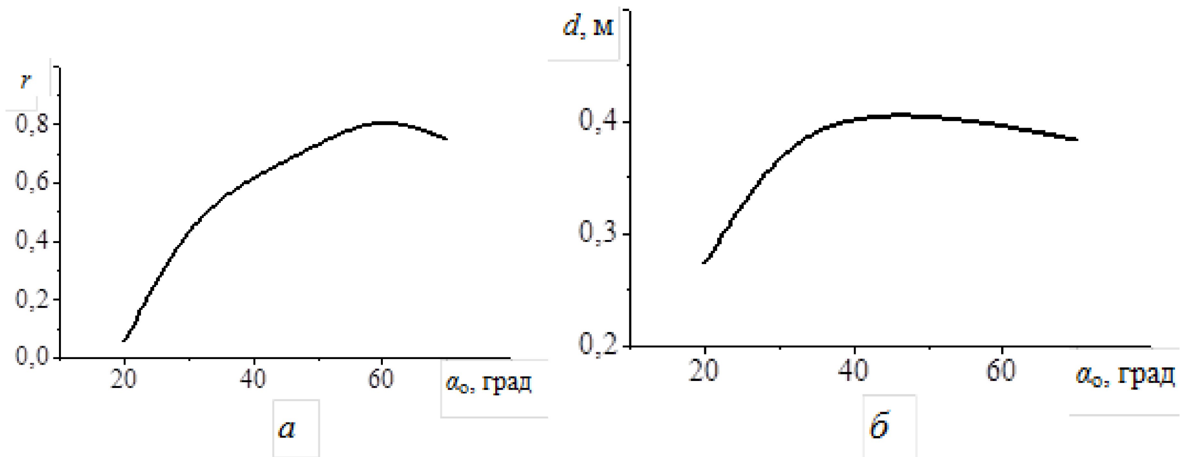


Figure 4 – Furrow shape with different blade installation parameters

Too low position of the moldboard ho (at the top) or too small transverse angle of inclination αo (at the bottom) lead to "pressing" of the seam and disruption of the furrow shape. Thus, the optimal position of the moldboard, providing high turnover of the seam and low energy costs is ho = –0.18 m. The next series of computer experiments was carried out with a change in the angle αo of the moldboard inclination from 20o to 70o with a step of 10o (Figure 5). In general, the course of the dependencies NΠ(αo), NB(αo) and r(αo) is similar to the previous case, since a change in the angle of inclination of the moldboard at a fixed point B of its junction with the disk is equivalent to a change in the distance from the moldboard to the soil level. At αo = 60o, the maximum turnover coefficient r is observed. In addition, the dependence of the transverse displacement of the formation d(αo) also has a maximum at αo = 40o. With an increase in the transverse angle of the dump from 40o, its plane moves away from the soil, and it has a smaller effect on the displacement of the formation. On the other hand, with a decrease in αo from 40o, the dump penetrates the soil more and more, destroys and mixes the formed formation, and the efficiency of the formation displacement decreases sharply (Figure 5 b).



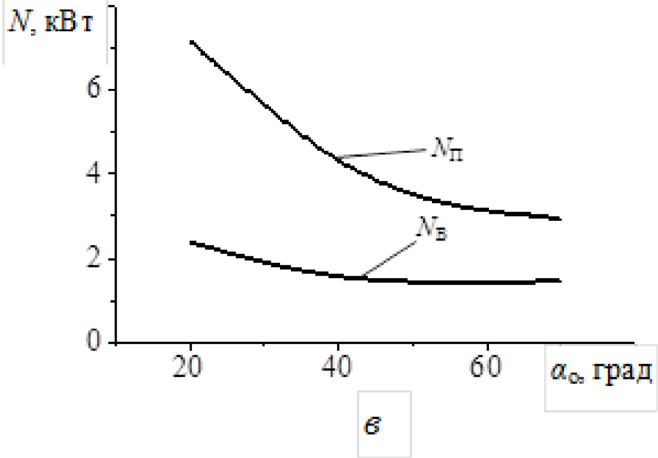


Figure 5 – Effect of the angle αo of the moldboard tilt on the quality (a, b) and energy (c) indicators of soil cultivation: NП – power expended on the forward movement of the plow; NB – power expended on the rotation of the plow disk.

It should be noted that at small angles αo, practically zero values of the coefficient r are achieved (Figure 5a). This means that the formation in this case shifts without turning over. In the next series of computer experiments, the longitudinal angle βo of the dump installation was changed from –30o to –10o with a step of 5o (Figure 6). As can be seen from the graphs, NB and r are practically independent of βo. The absence of dependence is apparently due to the fact that the soil mass enters the dump from below, rising along a spherical disk. Therefore, the main effect of the formation turning over is caused by the installation of the dump at a certain transverse angle αo, and not βo. The angle βo would have an effect if the soil mass entered mainly in the longitudinal direction.

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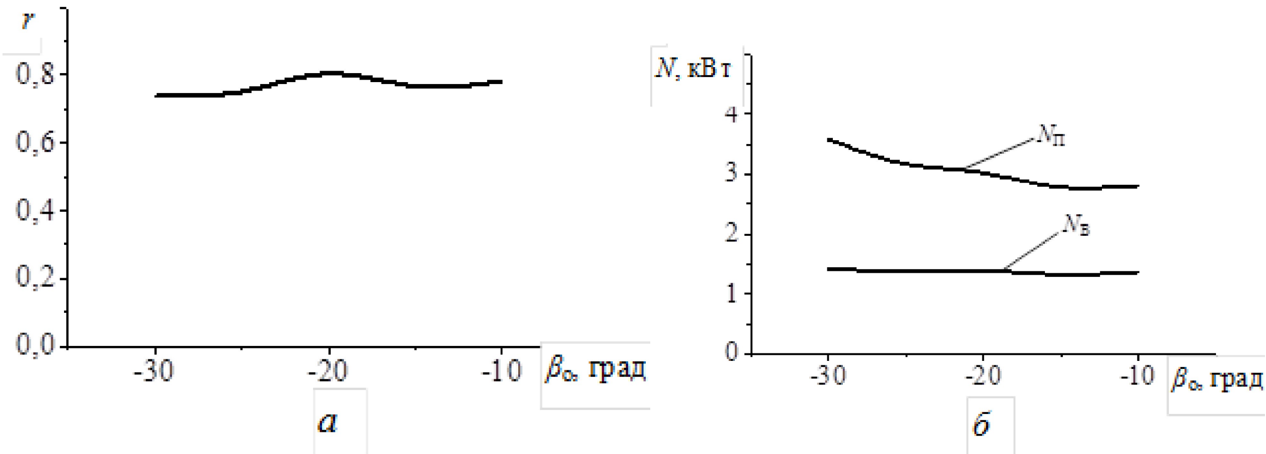

Figure 6 – Effect of the angle βo of the moldboard tilt on the quality (a) and energy (b) indicators. NП – power expended on the forward movement of the plow; NB – power expended on the rotation of the plow disk.

Some growth of NП with decreasing βo, as before, can be explained by the fact that the moldboard plane begins to "touch" the uncultivated soil. The graphs of NП(βo), NB(βo) and r(βo) constructed for αo=60o demonstrate almost complete absence of functional dependence. However, at small values of αo, for example, at αo = 30o, the listed dependences are very strong. This will be shown below during the optimization of the main parameters of the plough. Thus, the efficiency of the moldboard is most influenced by the parameters ho and αo. In addition, when installing the moldboard, it is necessary to provide some clearance between the moldboard and the soil level. The shape and position of the disc plough moldboard have a significant effect on the efficiency of soil cultivation. In particular, it is important to know what the angles αo and βo of the installation of the main plane of the moldboard should be so that the energy costs for soil cultivation are low and the quality of cultivation is high. This will allow formulating recommendations for equipping a disc plow with a moldboard. Parametric optimization of complex systems in the general case is reduced to the problem of finding the extremum of a function of several variables. In this case, it is necessary to determine such areas of change in the input parameters, in which the material parameters satisfy some accepted criterion, or several particular criteria [3]. In order for the optimization criterion to comprehensively characterize the system under study, it is usually composed as a linear combination with the corresponding weighting coefficients of several partial optimization criteria ki, which are economic or qualitative indicators [4]. In this case, it is advisable to use the power N(αo, βo) spent on translational motion and rotation and the turnover coefficient r(αo, βo) as partial criteria. Thus, it is necessary to solve the following optimization problem: simultaneously minimize the function N(αo, βo) and maximize the function r(αo, βo) by means of a coordinated selection of the factors αo and βo. In the process of optimizing the blade installation angles, the same intervals of factor variation were used as at the stage of systematic studies: the transverse angle αo was varied from 30 to 70 degrees in 10-degree increments, the longitudinal angle βo was varied from –30 to –10 degrees in 5-degree increments. In this case, two computer experiments were conducted at each of the 25 points (αoi, βoi) with subsequent averaging of the obtained results Ni and ri. Next, to smooth out random errors, the dependencies N(αo, βo) and r(αo, βo) obtained in tabular form were approximated by a second-order polynomial surface (Figure 6), according to which optimization was performed [5].

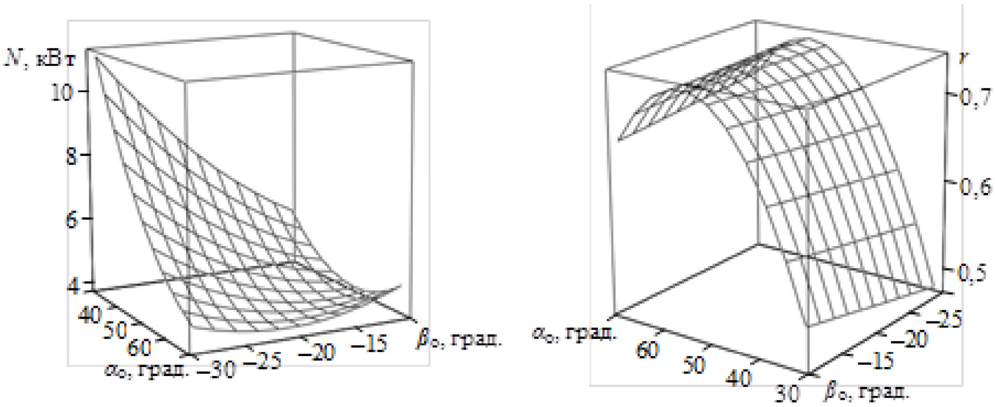

Figure 7 – Response surfaces N(αo, βo), r(αo, βo), N(ho, ω), r(ho, ω): on the left – results of a computer experiment, on the right – approximating surfaces

An important advantage of two-factor optimization is the ability to graphically depict response surfaces and conduct their visual analysis (Figure 7). By analyzing each of the response surfaces, represented using level lines, we can conditionally divide the factor space into two areas: favorable (shaded in Figure 8), in which the particular optimization criterion takes the desired minimum or maximum values, and unfavorable. A certain level line is selected by experts as the boundary between the favorable and unfavorable areas. In this case, it is necessary to take into account a number of requirements [6]: - the favorable area should contain the most extreme (maximum or minimum) values of the criterion; - in the favorable area, the criterion, if possible, should be more or less constant; - the favorable area should occupy a significant share of the factor space (20-40%). In this case, the power isoline N = 5 kW, the isoline of the turnover coefficient were selected as the boundary r=0,75.

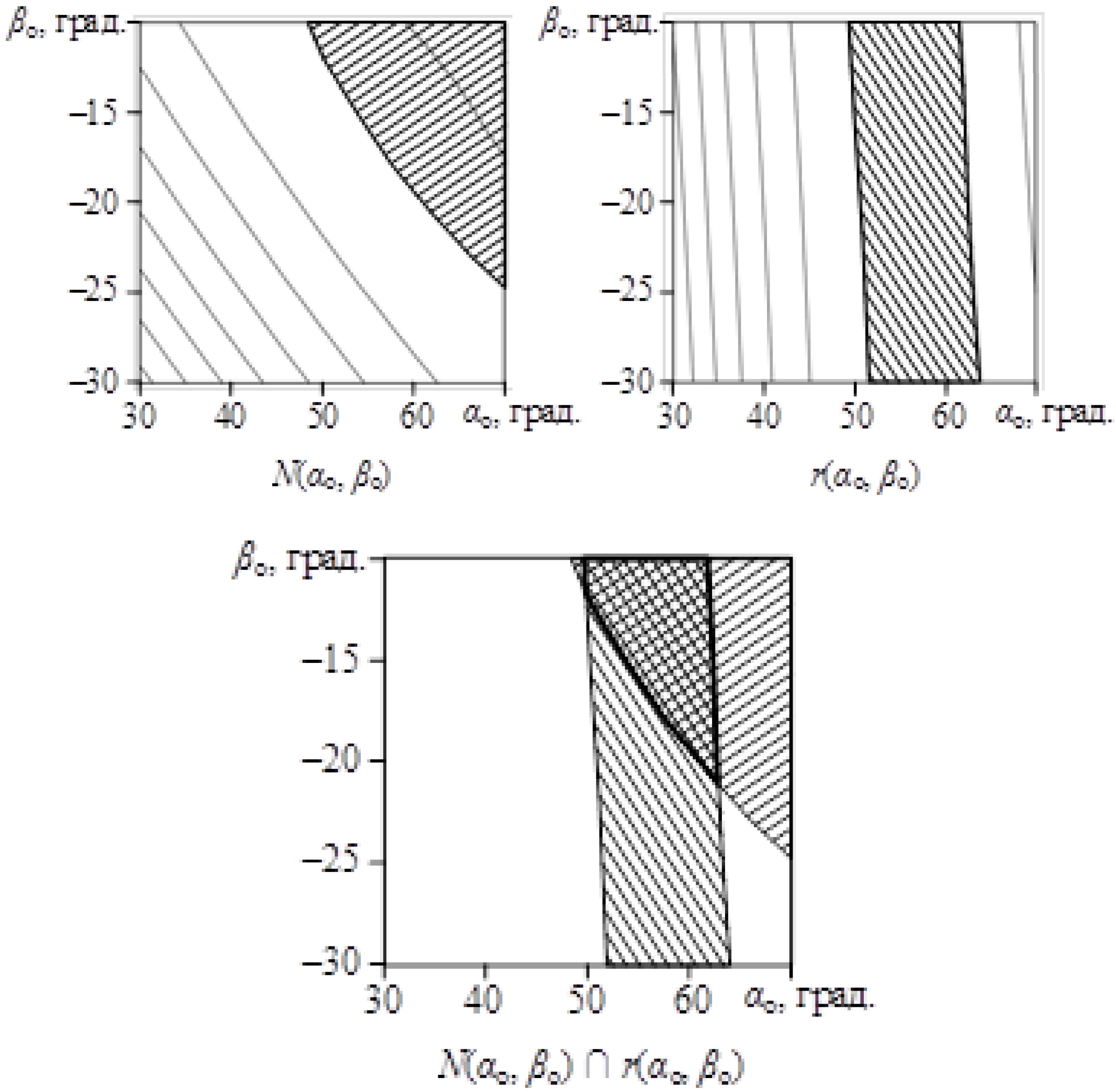

Figure 8 – Favorable regions of factor space (shaded) on response surfaces

Joint consideration of the configuration of favorable regions in the factor spaces N(αo, βo) and r(αo, βo) allowed us to conclude that the optimal values of the parameters αo and βo are contained in an approximately triangular region shown in Figure 8c. The optimal ranges of the factors are 50O<αo< 65O; –20O<βo< ¬–10º. The fact that the optimal region occupies a significant area of the factor space indirectly indicates the low sensitivity of the proposed design to operating conditions and therefore guarantees stable operation of the proposed design.

Conclusions

1. A simulation computer model of the interaction of a disc plough with soil has been developed based on the finite element method. The model allows one to determine energy costs and the quality of soil cultivation based on the specified parameters of the plough, soil and operating conditions.
2. Equipping the plough with a mouldboard significantly improves the quality of soil cultivation: the turnover of the layer increases by 14%, fragmentation of the layer decreases, the furrow has a more distinct rounded shape, and the cut layer is thrown further in the transverse direction, which reduces the likelihood of the layer falling back into the furrow. At the same time, power costs increase by only 8.6%.
3. When choosing the configuration of the mouldboard and its location relative to the disc, it is necessary to be guided by the following requirements: - the mouldboard in combination with the

spherical surface of the disc should create a helical surface; - the cut layer, rising along the rotating disk, should reach the moldboard earlier than it would fall off the disk; - the moldboard should be installed with some clearance from the soil level (approximately 5 cm).
4. The height of the moldboard location (in relation to the disk axis) should be selected depending on the depth of soil cultivation. With a cultivation depth a = 15 cm and the adopted moldboard configuration, the optimal position of point. B is 20 cm below the disk axis.
5. The optimal ranges of the moldboard installation angles αo and βo, ensuring both minimal energy consumption and high turnover of the layer, are as follows: 50O < αo < 65O; –20O < βo < ¬–10O.
6. Coordinated optimization of the height of the moldboard location ho under the conditions of minimum energy consumption and high turnover of the layer made it possible to determine the optimal ranges of the factors: –22 cm < ho < –13 cm.

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Bosishga ruxsat etildi: 25.04.2025 y.
Ofset qog‘oz. Qog‘oz bichimi: 60x84 1/16.
“Cambria” gar. Ofset bosma.
Hisob nashriyot t.: 35,17. Shartli b. t.: 35,25.
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